THE

INTEROCEANIC PROBLEM,

AND

Its Scientific Solution.

AN ADDRESS

Before the American Association for the Advancement of Science,

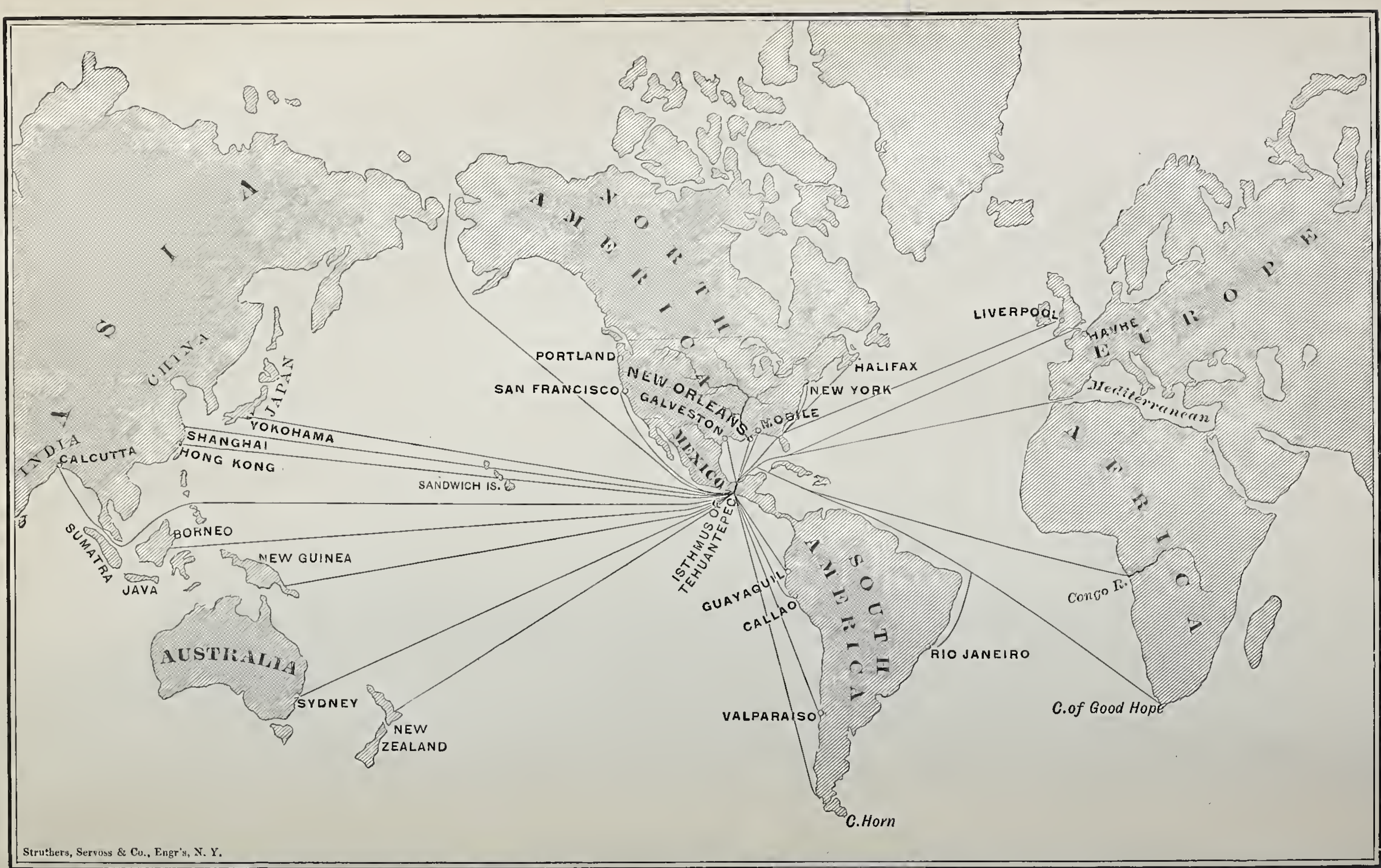
BY

ELMER L. CORTHELL,

CIVIL ENGINEER.

THIRTY-FOURTH MEETING, ANN ARBOR, MICHIGAN,

AUGUST 26, 1885.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LADIES AND GENTLEMEN :

We come before you, representatives of the Advancement of Science, to present one of the most important scientific and commercial problems of this age.

The subject (however unworthily it may be treated by us) is full of active interest to men representing all those sciences that have to do with the advancement of mankind. To geographers, biologists, anthropologists, economists, chemists and civil and mechanical engineers, this subject, so importantly affecting man in his agricultural, industrial, commercial, social and political relations, is exceedingly attractive. It must be a source of pride also to you, the direct descendants and representatives of the science of the ages, to know that from you and from those patient and able men of the past, have come forth the means for overcoming an obstacle that turned Columbus back from his search for the Indies and baffled Cortez in his efforts to reach the Pacific and its long sought for islands and countries.

More than three centuries and a half have passed and with them have not only come new and greater wants among mankind, but new and greater resources and power. Our wants develop, but our power develops also. Whatever necessity may arise in any age, science always furnishes the means to supply it.

One of the greatest wants of *this* age is prompt, free and economical exchange of its productions, and the removal of the obstructions to its industries and commerce. The railway, telegraph, ocean cable and the steamship have supplied wants, but have

created greater ones. No nation of the earth can now afford to be a stranger to any other. Distance and time must be annihilated. The improvement of the means of communication to ensure speed and economy is the study of the age. One barrier broken down, our efforts need all the more to be expended on the next that stands in the way. Some mountain range that stood unnoticed and even undiscovered, when the Red Man roamed over its slopes and through its passes, becomes a most serious obstacle when the surveys of the engineers place it in the projected pathway of the locomotive.

The obstacles to commerce one after another have disappeared. The building of the iron ship and the invention of the propeller have brought the two shores of the Atlantic within a week of each other. The ocean cable has reduced the week to a moment. The network of telegraph wires spread over the continents makes near neighbors of far removed districts. The steel ribbons and the iron horse bind together distant sections. The Suez Canal, cut through the marshes of the Egyptian desert, from the Mediterranean to the Arabian Gulf, has shortened the distance from England to Calcutta forty-five hundred miles, revolutionized the carrying trade of the world and made it possible for England to hold, civilize and develop all her eastern possessions. In every direction civilization, through its numerous improvements in transportation, shortens distance and reduces the cost of moving the products of the world.

But, while all this wonderful advance is recorded, there lies here (see frontispiece) in the centre of the world, midway between the far Pacific and Atlantic countries, with a broad ocean on either hand, a continent extending nearly the whole distance from the North to the South Pole, without a passage-way anywhere for ocean or coastwise commerce. Brave men and able navigators, some of whom have laid down their lives in the frozen seas, have for many years, supported by the civilized governments of the world, sought in vain for the Northwest Passage around this obstacle to commerce. The only practicable opening between the east and the west lies between Cape Horn and the Southern Pole. Stretched along the western coast of this great continent from the extreme North to the far South is an immense wall of rock, piled up by nature so high that it forms an effectual barrier to the necessary economies of the age. If in the northern part of the narrow neck of land, that unites the great mass of the northern and southern halves of the continent, Nature in her ancient convulsions had rent the land asunder, mingled the seas and opened a capacious passage-way, as at the Straits of Magellan or Gibraltar, we would not be

here this evening to state and discuss this important interoceanic problem. She did not do this work for us, but she provided a place the most convenient for a passage-way, and there so arranged the harbors, rivers, valleys, depressions between the mountains, the slopes of the country and the constructive materials, that the advanced science of this century might build a way *over* where she, with all her mighty forces, could not break a way *through.*

In order to fully appreciate the importance of promptly, effectively and economically solving the Interoceanic problem, it is necessary to study carefully the relations of the countries of the world to each other; to obtain detailed information of the character and volume of their productions, the routes by which they now move and the demand that exists in one country for the agricultural, manufactured or mineral products of other countries. It is necessary to understand the peculiarity of the laws of trade in different countries. We need information also about the character of the races and the nations, their history, their methods of business, their development or decadence—in fact the whole commercial, industrial and political subject in all its various forms must be familiar to us. With such information possessed there will certainly come to us the belief—nay more, the conviction—that the importance of uniting the Atlantic and Pacific oceans for commerce cannot be understated, and that, if there is aught in Science to produce the grand result desired, it should be called on for its best assistance and its latest discoveries, in order that the correct principles and the most powerful appliances may be combined in a successful effort to overcome the barrier.

Taking up a few only of the commercial reasons for this important work, we call your attention, in the first place, to the fact that although the continent has been crossed by five lines of railroad they cannot profitably transport many important bulky products. The cereals and the valuable woods of the Pacific coast cannot reach European markets by these trans-continental routes; even the Panama Railroad, hardly fifty miles in length, cannot afford to do this work, so great is the expense of trans-shipment; in fact, the trans-continental railroads, over three thousand miles in length, can carry goods with less cost than can the Panama Railroad Route. The cereals, nearly 1,200,000 tons per annum, still pursue their voyage of sixteen thousand miles, around Cape Horn, occupying from four to five months, to reach the market of the world at Liverpool. The importance to our Pacific coast of shortening the distance for this commerce alone will be seen by the following facts. It

costs only eight cents per day for labor to raise Indian wheat. England has expended, and is still expending millions to irrigate this vast and populous country. She is extending the railroad system to its most remote districts in order to transport the wheat to the seaboard, and she then brings it to her ports by the shortened route of the Suez Canal. Still our Pacific States, with their admirable climate and fertile soil, can compete successfully in the world's markets if we can shorten the route one-half, the time two months and relatively reduce the cost of transportation. The valuable and inexhaustible woods of the Pacific will find a ready market on both the Atlantic coasts if an all-water route can be obtained eight thousand miles shorter than by Cape Horn.

The Isthmian barrier not only prevents the development of our own Pacific coast, but obstructs and hampers the important commerce of the west coast of South America. The extensive and valuable products of Colombia, Chili and Peru must pass southward around Cape Horn on a circuitous route to New York or Liverpool. Again, in the interchange of our manufactured goods for the raw materials of the Pacific coasts, Australasia, Malaysia and Polynesia, we are debarred from these important markets by the same insurmountable obstacle. By the impetus given to the development of the far Pacific countries by the opening of the Suez Canal, their commerce has increased *one hundred and fifty* per cent. in the last five years, and now amounts to nearly two billion dollars per annum. Australia alone has a railway system six thousand miles in length and a foreign commerce of about four hundred million dollars. She imports from us a small quantity of nearly all of our manufactured articles, which find their way thither by many indirect and expensive routes, and generally in foreign ships. It is interesting to note the routes by which many products move. Of the tea shipped from Japan to New York last year, about one-half, sixteen million pounds, went across the Pacific to San Francisco, and was there put aboard the cars and hauled across the continent ; the other half went down the Asiatic coast, through the Indian Ocean, Suez Canal, the Mediterranean and across the Atlantic Ocean. On account of our inability to reach Pacific ports, and the absence of our ships there, many of the goods shipped from Peruvian and other South American ports to New York are sent to Liverpool on English ships, and are thence re-shipped across the Atlantic. Of all the vast commerce of the Pacific our country enjoys only *four per cent.*

Forty-five millions of our people live east of the Rocky Moun-

tains, and produce nearly all the manufactured goods of the country which amount annually to the enormous total of over *five billion dollars* ($5,000,000,000) in value. Not being able to reach economically or promptly the countries that have need of these manufactured articles, we export but *two per cent.* of them, and must yield to those countries of Europe which manufacture them at less cost and are much nearer to the markets. The annual *internal* commerce of the United States however, amounts to $12,000,000,000—400,000,000 tons. *One train of cars transporting this freight would girdle the earth seven times.* Special attention is called to the unfortunate position of the Mississippi Valley and its seaports on the Gulf ; with only eight hundred miles between them and the Pacific, they cannot reach it except by a voyage around Cape Horn, which absolutely prevents the interchange of business. Our whole eastern and southern coast can send its products *Eastward*, but to the *Westward* is an impassable barrier, and Westward are six hundred million people just now opening their rich treasures to civilization and commerce. The dwellers on the west coast of South America, Mexico and our own Pacific coast, although seemingly our nearest neighbors, are practically removed farther from us than the East Indies are by way of the Suez Canal.

The over-sea commerce of the globe is now upwards of fourteen billion dollars, and is increasing at the rate of *seventy-five* per cent. every decade ; so that, if ten years ago it was important to solve the Isthmian problem, it is more important to-day, and will be still more so ten years hence. Had we time and space we could bring forward a mass of evidence in detail that would prove the absolute necessity of a passage-way through or over the narrow neck of land separating the two great oceans. For nearly four centuries this important subject has been before the world with continually increasing interest

A volume could be written giving the history of the attempts of governments, companies and individuals to find a passage-way for commerce across the American Isthmus. England, France, Spain, Portugal, The Netherlands and the United States, as Governments, have from time to time interested themselves in explorations of the country. Beginning at the Southern extremity, surveys have been made by Galva of Portugal in 1550 ; Galestro of Spain in 1780 ; Humboldt, Garella, Trautwine, Kennish, Mitchler, Craven, Strain, Collins, Selfridge, Wyse, Reclus, Childs, Hatfield, Lull, McFarland, Menocal, Moro, Barnard, Williams, Shufeldt, Garay and Van

Brocklin. The records of their surveys are on file with the governments, companies or individuals by whom they were employed. Statesmen, economists, commercial men and engineers have always taken a deep interest in the subject: Of our own statesmen Jackson, Webster, Buchanan, Fillmore, Cass, Grant and Arthur were especially active in urging interoceanic communication. The statesmen of Mexico, from Cortez to General Diaz, have been urgent for it, and the same may be said of the statesmen of the smaller states of the Isthmus. In plain and forcible language, General Grant said in 1881, in the *North American Review:*

"The States of North and South America, lying along the "Pacific, furnish in large abundance those commodities which "are constantly needed in the markets of almost every country "of Europe. Of guano and nitre the trade is immense. From "the ports of Chili, nearly four hundred thousand tons of "freight are shipped eastward annually. More than one "million tons of grain are shipped each year from the Pacific States "and Territories. There is no doubt that more than 4,000,000 "tons of merchandise find their way from the east and require "water communication, in order that they may be shipped econo-"mically and profitably, and this is merchandise to which railway "transportation across the continent is wholly inapplicable."

In a message to Congress last year, President Arthur thus earnestly presented the salient points of this important subject:

"While the enterprise of our citizens has responded to the duty "of creating means of speedy transit by rail between the two oceans, "these great achievements are inadequate to supply a most important "requisite of national union and prosperity. For all maritime pur-"poses, the States upon the Pacific are more distant from those upon "the Atlantic than if separated by either ocean alone. Europe and "Africa are nearer New York, and Asia is nearer to California than "are these two great States to each other by sea. Weeks of steam "voyage, or months under sail, are consumed in the passage round the "Horn, with the disadvantage of traversing tempestuous waters or risk-"ing the navigation of the Straits of Magellan. A nation like ours "cannot rest satisfied with such a separation of its mutually dependent "members. We possess an ocean border of considerably over ten "thousand miles on the Atlantic and Gulf of Mexico, and, including "Alaska, of some ten thousand miles on the Pacific. Within a gen-"eration the western coast has developed into an empire, with a large "and rapidly growing population, with vast but partially developed

"resources. At the present rate of increase, the end of the century "will see us a commonwealth of, perhaps, nearly a hundred million "inhabitants, of which the west should have a considerable larger and "richer proportion than now. * * *

"The relation of these American countries" (Pacific Coast of South "America,) "to the United States is that of a natural market from "which the want of direct communication has hitherto practically ex- "cluded us. By piercing the Isthmus the heretofore insuperable "obstacles of time, sea, and distance disappear, and our vessels and "productions will enter upon the world's competitive field, with a de- "cided advantage of which they will avail themselves. * * *

"It will bring European grain markets of demand within easy "distance of our Pacific, and will give to the manufacturers on the At- "lantic seaboard economical access to the cities of China, thus break- "ing down the barrier which separates the principal manufacturing "centres of the United States from the markets of the vast population "of Asia, and placing the Eastern States of the Union for all pur- "poses of trade, midway between Europe and Asia."

Without giving the detailed results of the many surveys and examinations that have been made of the American Isthmus, it may be said that the various routes have been resolved into three, viz: Panama, Nicaragua and Tehuantepec. The length of the Isthmus from Tehuantepec to Panama is about twelve hundred statute miles, or equal to the distance between New York and the Florida Straits. The Isthmus varies in height and width, now rising to a considerable altitude and now sinking into low depressions. At Panama it is scarcely fifty miles wide, at another point only thirty-one miles, at Nicaragua, following the natural depression, one hundred and eighty-six miles and at Tehuantepec one hundred and thirty-four miles, between navigable waters. At the Southern extremity of the Isthmus, there exists, on either side, a region of calms and baffling winds termed "Doldrums." This is caused partly by the peculiar configuration of the West India Islands, which present an almost continuous barrier on the east of the Caribbean Sea, and partly by the mountain ranges of the Isthmus, which offer a still more formidable obstacle to the passage of the north-east trades, throwing them high into the upper regions of the atmosphere and extending the calms far out into the Pacific Ocean, on the parallel of Panama. This whole region is shunned by navigators of sailing vessels, who often run a thousand miles out of their course to avoid it. The nautical conditions that exist at the Northern part of the Isthmus, near Tehuan-

tepec, are much different, and much more favorable to sailing vessels. Lieut. Maury, an undisputed authority in geography and navigation, stated that should a convulsion of nature rend asunder the Darien Isthmus, no sailing ship would use the strait thus formed, but in reference to the conditions existing in the northern part of the Isthmus his eloquent words are well worth giving :

"From the Gulf of Mexico, the great commercial markets of the
" world are down-hill. A vessel bound from that gulf to Europe,
" places herself in the current of the Gulf Stream and drifts along
" with it at the rate, for part of the way, of eighty or one hundred
" miles a day. * * * And when there shall be estab-
" lished a commercial thoroughfare across the Isthmus, the trade
" winds of the Pacific will place China, India, New Holland, and all
" the islands of that ocean down-hill from this sea of ours. In that
" case, Europe must pass by our very doors on the great highway to
" the markets both of the East and West Indies. This beautiful
" Mesopotamian sea is in a position to occupy the summit level of
" navigation, and to become the great commercial receptacle of the
" world. Our rivers run into it, and float down with their currents
" the surplus articles of merchandise that are produced upon their
" banks. Arrived with them upon the bosom of this grand marine
" basin, there are the currents of the sea and the winds of heaven,
" so arranged by nature that they drift it and waft it down-hill and
" down stream to the great market-places of the world."

Commodore Shufeldt said in 1871, in an official report of his survey of the Isthmus of Tehuantepec, "each isthmus rises into " importance as it lies nearer to the centre of American commercial " interests ; any intrinsic value of this eminently national work " ought to be based upon the inverse ratio of the distance from that " centre." An all-water route by way of Tehuantepec connects the east and west coast lines of the United States and Mexico, and renders our own territory circumnavigable, as it were.

Lying nearly ten degrees north of Panama, the climate at Tehuantepec is much more healthy and the heat less intense. In reference to the commercial advantage of this northern route, it needs no argument to prove that that route is the shortest. and, other things being equal, the best, which lies nearest the axial line of productions, population and business, which approximately may be assumed to pass through Hong Kong, San Francisco, New York and Liverpool. The Tehuantepec route is shorter than the Panama by from seven hundred to twenty-two hundred miles, depending

upon the ports to be connected. In general, the advantages of this northern route are, favorable winds, a healthy climate, great saving in distance, good harbors, a location in a strong neighboring republic, and not in an insurrectionary country with an unstable government, a defensible route and a country well adapted for what we consider to be the proper method of interoceanic transit, viz.: by a *Ship Railway.*

The great importance to this country to possess a route advantageous to sailing vessels, will be seen from the fact that there are, sailing under the American flag, six thousand two hundred and fourteen sailing vessels engaged in over-sea commerce, and only four hundred and twenty-two steamships. We can build wooden sailing ships cheaper than any other nation in the world ; the cost is about fifty dollars per registered ton, whereas in England it is seventy-five dollars, but England can build iron ships for fifty-five dollars per ton, whereas the cost in this country is seventy-five dollars. The interoceanic route that would prohibit sailing vessels would drive our commerce from the seas.

The preceding brief sketch gives the general conditions of the problem before us, geographical, commercial, industrial and political. The scientific solution of the problem is that one which most nearly satisfies these conditions, is most closely in accord with the science of this age, gives a method adequate, not only for the commerce of this, but the coming centuries, is best adapted to the country to be traversed, most economical in construction, maintenance and operation and will despatch vessels from ocean to ocean with the greatest speed and safety.

We propose, now, to describe and explain what we believe to be this scientific solution. We will attempt to show that the method by ship railway is far better than any other and is most nearly in accord with the scientific tendencies and developments of this last quarter of the nineteenth century, and is far more capable than any other method of meeting the wants of the coming ages. The following description, supplemented by the stereoscopic views of the plans and by the plates which accompany this address, will, we think, prove the practicability and the economy of the ship railway.

The ship railway involves no new principle, but the application on a large scale of the principles and appliances that are well-known among scientific and practical men. The hauling of vessels and of boats overland is no new thing. It has been done in various countries and at different times in all parts of the civilized world, from

four hundred years before Christ, when the Athenians transported their immense triremes of about one hundred and fifty tons weight, over the Isthmus of Corinth, to this day, when large ships are hauled out of the water on marine railways, or lifted on hydraulic docks and then hauled ashore. It is interesting to note that Emmanuel Swedenborg, under Charles XII of Sweden, at the siege of Frederickshall in 1718, transported some vessels over fourteen miles of rough country, by rolling machines of his own design. We therefore simply utilize for a great work what science has taught and developed during the last twenty-three hundred years.

Twenty-five miles from the Gulf, at Minatitlan, in the broad, deep river Coatzacoalcos, a basin will be excavated to admit the vessels to the lifting dock, which will be constructed of steel plates with substantial bulkheads in each direction, and will be about four hundred and fifty feet long, seventy-five feet wide, and from twelve to fifteen feet deep, and capable of raising vessels of from six to seven thousand tons weight. One of the objections that is continually urged against lifting loaded vessels is the fact that they would bring upon the carriage, or car, unequal weights. One of the special designs of the dock is an appliance for equalizing the weight of the vessel and distributing it perfectly over the whole area of the carriage which tranports it. This distribution of weight is effected by a system of hydraulic rams or presses. These rams are situated on a deck placed about six feet below the upper deck of the lifting dock, or pontoon. They are arranged so that there will be the same area of pressure on every cross line. These cross lines are spaced six feet and seven inches apart, and the number in each line corresponds to its position under the vessel; those under the midship section of the vessel having seven rams; those nearer the bow or stern five and then three rams; while under the bow or stern the whole supporting area is concentrated into one ram. These rams are also arranged in seven longitudinal lines: one, composed of the most powerful rams, under the keel and one on each side under the bottom, bilges and sides of the vessel. These rams, one hundred and thirty to one hundred and fifty in number, are all connected together by pipes, and the whole system is actuated by steam pressure pumps, which are placed on the top of towers that are connected with the pontoon and move with it, but are not submerged when the pontoon goes into the water. These rams have a range of movement of seven or eight feet, which permits them to take the shape of the vessel, whatever its model may be. The carriage transporting the vessel is supplied

with corresponding supports, so placed in the carriage that they can be brought directly over the rams in the pontoon. The carriage has a continuous keel-block running from one end to the other. The other supports are provided at the upper end with a broad surface hinged with a universal joint, so as to take the shape of the vessel. These supports, as well as those under the continuous keel block, move freely in the girders of the carriage and project below them when the carriage is in position on the pontoon. The principal strength of the carriage is in its cross girders, the short longitudinal girders connecting them being intended only to transfer the weight to the wheels. In order to raise the vessel the carriage is run upon the pontoon, which is provided with six rails, and is locked in position so as to bring the supports directly over the rams. The water is then let into the dock and it sinks to the foundations in the bottom of the basin, or to a sufficient depth to allow the vessel to be floated in over it without interfering with the supports of the carriage. The water is then pumped out of the pontoon by means of powerful centrifugal pumps, and it rises up under the vessel. Just before coming into contact with it, the pressure pump is set at work, and the rams rise up under the keel block and the other supports, bringing them up to the hull of the vessel. As the pontoon continues to rise, bringing the vessel with it, the rams, on which the supports rest, equalize the constantly increasing weight and distribute it in such a manner that, when the vessel is entirely out of the water and its weight rests upon the rams altogether, they bear it equally from stem to stern and from side to side, which equality of pressure must necessarily result from the peculiar arrangement of the areas of the rams, previously described. A thread is cut in the supports, in which moves an adjusting nut, or hand-wheel, which is run down to a bearing on the upper plate of the cross girders. When this work has been performed, the valves of the pressure pumps are opened and the water is allowed to escape from under the rams, when they recede downward into the pontoon, leaving the vessel supported on the carriage exactly as it was supported on the rams.

In order to compel the pontoon, as it is raised or lowered, to move in a perfectly horizontal plane, hydraulic governors are attached to the corners of the pontoon and the outside dock ; the mechanism of these governors being as follows : An upright cylinder on each corner of the outside dock is connected by a pipe with an inverted cylinder on the opposite diagonal corner. Attached to each corner of the pontoon are two plungers, which move in the cylinders ; one

of these plungers being upright and the other inverted. The cylinders and the pipes are filled solid with water. When the vessel is being raised out of the water a greater weight may be brought upon one end of the pontoon than upon the other, as it would be impossible to bring the vessel in so that its centre of gravity would be exactly over the centre of the pontoon. The effect would be that one end of the pontoon would not be able to rise as rapidly as the other end ; this would cause the pontoon in its movement to bind upon the guiding cylinders, upon which it moves, and thus prevent its further movement. One-half the preponderance of weight is suspended on one plunger at the heavy end and one-half upon the other ; this brings a pressure upon the water in the cylinders which immediately reacts through the pipes in the top of the cylinders at the diagonal corners, and exerts the same amount of downward pressure upon the plungers in those cylinders. This compels the pontoon to rise and fall perfectly level. These governors also serve the important purpose of determining by a pressure gauge what the preponderance of weight is. If the gauge should show it to be more than it is possible to equalize upon the carriage, it would be necessary to lower the pontoon and re-adjust the position of the vessel over it. The time required to lift the maximum sized vessel is from fifteen to twenty minutes. It is practicable to perform the whole work of bringing the vessel in, raising it, and adjusting the supports ready for transportation on the railway, in thirty minutes time.

The road-bed will be constructed of the best materials which can be found. It will be about fifty feet in width. There will be under the ties two feet of broken stone ballast ; these ties will be about forty feet in length, formed of steel plates on which will rest the steel rails, whose weight will be from one hundred to one hundred and twenty pounds per lineal yard. In other words, a perfect marine railway will be constructed from one terminus to the other which will be abundantly able to hold up the heaviest weight that may be placed upon it. It will readily be seen that the distribution of weight, by the system of rams, not only allows us to bring a uniform weight over each wheel, and one that it is abundantly able to sustain, but also distributes the weight over a large area on the road-bed, and thus prevents a concentrated weight being brought upon any part of it. The maximum load to be transported will not bring upon any one wheel more than eight and one-half or nine tons. These wheels will be tested, when manufactured, to twenty tons. There will be over each wheel a powerful spring, which will also be

tested to twenty tons, and will have a movement of six or seven inches, so that when the greatest load is upon it, it will not be closed within three or four inches. This gives an elastic bearing for the vessel and carriage. If there should be any irregularity in the track, these springs will serve to take it up, without bringing any undue weight upon the wheels.

The vessels will be hauled across the Isthmus by powerful locomotives. The engines, such as have been built recently by the Baldwin Locomotive Works of Philadelphia, for the Dom Pedro Railway in Brazil, have sufficient power. That company guarantees that three such engines, weighing sixty-five gross tons each, will haul the maximum sized vessel at the rate of fifteen miles an hour, if necessary, on grades up to twenty feet to the mile. A system of adhesion and rack-rail combined, has been recently put into practice on a railway in the Hartz mountains, which it is claimed has double the power of the ordinary locomotive hauling by adhesion alone ; experimental tests, with a fifty-four ton engine, built on this principle, showed that a train of two hundred and fifty tons weight could be hauled at twenty miles an hour on a *six per cent.* grade ; could be stopped on that grade, and backed, and hauled ahead again without any difficulty. The grades to be overcome at the Isthmus of Tehuantepec are very light. The larger part of the distance is practically level ; there is one grade of one per cent. twelve miles in length.

The railway traverses a succession of valleys. In the hilly part of the Isthmus, in order to avoid heavy construction work, it is necessary to make abrupt changes of direction. As it would be impracticable to move a rigid carriage of such great length with a vessel upon it, around a sharp curve, these changes of direction, five in number, are made by floating turn-tables, which are simply great pontoons, or floating docks, which are placed in a segmental basin of masonry or concrete. When the vessel is drawn upon the pontoon the latter rests solidly upon the circular bearers in the bottom of the basin ; stability being given to it by the weight of water in it. In order to turn the pontoon to the new direction required, the water is pumped out of it sufficiently to just raise it from the foundations on which it rests. It is then, while floating, turned about a central pivot ; although the weight does not rest upon the pivot, but entirely upon the water. When the pontoon is revolved so that the rails upon it coincide with the rails of the railway, in the new direction, the water is admitted to the pontoon and it again rests upon the circular bearers. The vessel is then hauled off the pontoon upon the railway.

These turn-tables will be utilized for passing points, or sidings—so that while the railway is virtually a single track road, vessels may meet and pass each other. By laying radial tracks from these basins, vessels can be run out, as on marine railways for cleaning, painting and repairing. About $1000 will thus be saved to the vessel over the cost of docking in ports. Considerable work of this kind can also be done while the vessel is in transit.

The admissible lateral motion in the journals and on the treads of the wheels is sufficient to make a curve of 20 miles radius perfectly practicable. The curves laid down on the location of the railway are from 20 to 53 miles. By these curves advantage is taken of the general lines of the country, and serious obstacles are avoided.

A vertical curve at the changes of grade, of about the same radius, is admissible by utilizing the movement of the springs and the elasticity which the carriage and its burden have in a longitudinal direction.

It is expected that the practicable speed will average eight or ten miles an hour, and it is intended to so construct the whole work, road-bed, rolling stock and other appliances as to make this speed perfectly safe. The whole distance is one hundred and thirty-four miles, and it is estimated that eighteen or twenty hours is amply sufficient to transfer the vessel from one ocean to the other.

In laying out and constructing the road-bed, the possible future enlargement necessary for larger vessels, wider carriages and greater traffic will be provided for by building the foundations sufficiently wide to permit double tracking the railway. The docks at the termini can also be duplicated, or even triplicated, when commerce demands it.

There are, on either side of the Isthmus, natural harbors, which with comparatively inexpensive improvements, can be made ample for the accommodation of the business. The surveys of the Isthmus, which have been very extensive and detailed, embracing all the information necessary for a reliable estimate, show that suitable materials are conveniently at hand for constructing the work; and that the total cost, including the improvements of the harbors, the mechanical appliances, rolling stock and a full equipment of everything necessary for operating the railway will not be over fifty million dollars in cash.

It is impossible in a brief address to give all the details that may be necessary for a complete exposition of the mechanical appliances to be used in the ship railway, but as the subject has been

fully considered by a large number of prominent scientific and practical experts, their opinions will serve to give corroborative proof of the practicability of the plans. Brief extracts only can here be given from, in many cases, lengthy opinions furnished by these experts.

Sir Edward J. Reed, for many years chief constructor of the British Navy, who has given the matter much study, states: "I affirm that the general structural strains which are likely to be brought upon a ship by lifting and transporting her, presuming, of course, that reasonable skill and care are applied to these processes, are inferior, much inferior to those strains to which every ocean-going ship is continually liable at sea. * * * As regards the comparative economy of transporting a ship's cargo by canal or railway, I am inclined to believe that the railway would prove the more economical of the two. * * * I have, therefore, no words but those of encouragement for a ship-railway, regarded from my point of view as a ship-builder, accustomed for a life time (which is getting now to be a long one) to the designing, building, repairing and docking of both wood and iron ships."

Mr. Nathaniel Barnaby, present chief constructor of the British Navy says: "I note, therefore, the question you wish to put to me, which is: 'do I think the problem insoluble of constructing a car on which a fully loaded ship can be safely transported over such a railway as could be built through a tolerably level country?' In reply to this, I say not only that it is soluble, but that the solution is, in my opinion, fairly indicated in your plans as laid before the committee on Inter-Oceanic Canals and shown to me. Ships which would be strained by ordinary docking would be liable to be strained also when suspended on a car not specially designed for their crazy condition; but such ships would be still more strained in their ordinary sea passages."

Mr. William John, recently scientific adviser of Lloyd's Register, and Mr. Martell, present adviser of Lloyd's, have both given unequivocally a favorable opinion of the ship railway.

Mr. George Fosbery Lyster, Engineer-in-chief, Liverpool Docks, states: "I have now been able to give the whole matter, as far as its engineering features are concerned, very careful consideration, and have concluded that if the permanent way, cradle arrangements, and general details are carried out in the ingenious and substantial manner you described, there will, in my judgment, be little or no difficulty in transporting properly constructed ships from sea to sea with entire convenience and safety."

Mr. John Fowler, who, as consulting engineer of the Egyptian government, projected a ship railway for the first cataract of the Nile, states: "After a very careful investigation of the alternative plans of canal and ship railway on the spot, I decided in favor of the railway; having satisfied myself that there was no mechanical difficulty in carrying ships of any size, without injury to themselves, on a properly designed car or cradle over a solidly constructed railway."

Mr. E. Leader Williams, Chief Engineer of the Manchester Ship Canal and of the Trent and Mersey Canal, and originator of the celebrated Anderton Hydraulic Canal Lift, states: "I believe that your ship railway only requires carrying out into execution to prove most successful in every way."

Messrs. Clark and Standfield—Mr. Edwin Clark having been the chief assistant of Robert Stephenson in the building of the celebrated tubular bridge over the Menai Straits, and who introduced the hydraulic vertical lift system at the Victoria Docks, and at Malta and Bombay, say: "We apprehend no difficulty in perfecting the necessary details of the plans, so as to insure the safe transportation of the largest loaded ships on the railway cars with absolute safety."

Emerson, Murgatroyd & Co., who, as contractors, built the hydraulic docks at Malta and Bombay, and the Anderton lift, say: "We have no hesitation in guaranteeing the lifting of a fully loaded ship or steamer of 8,000 or 10,000 tons' weight on a railway car from the sea or harbor level to that of your permanent way in 30 minutes, with absolute safety to the ship and the works, where the lift is not over 50 feet vertically. We will undertake to construct all the plans and works necessary to do this at each end of your line, and complete everything ready for attaching the locomotive to the car on which the ship is to be lifted and transported; this car, or any number of them, we will furnish also."

Mr. William Pearce, sole proprietor of John Elder & Company's works, Govan, Glasgow, and who built the Arizona, Elbe, Alaska and Etruria, and others of the finest steamers afloat, says:

"I am of opinion from what I know of the working of iron floating docks that I have designed and built, that iron steamers of 4,000 to 5,000 tons displacement may be docked, loaded, without any injury whatever. It is also my opinion that a ship railway for vessels of this size may be constructed and worked successfully, provided the land is solid and the line moderately level."

Mr. B. Baker, one of the ablest engineers of England, and at

present chief engineer of the great bridge now being constructed at the Firth of Forth, states :

"The general laws affecting the strength of materials apply to iron and steel ships as to other metallic structures, and in order to show that any of the above injuries could result, I have satisfied myself, by long and careful investigation, it is first necessary to assume either criminal negligence or a singularly badly designed car. In other words, apart from all practical experience in dry docks and elsewhere, it can be theoretically demonstrated that a vessel which would not break up at sea in an ordinary gale, would not be injured by transport in a well-constructed car, on a suitably formed railway."

Professor Francis Elgar, Fellow of the Royal School of Naval Architecture, and until recently general manager of Earle's Ship Building and Engineering Company, and a naval architect of recognized ability, states :

"As to transporting a loaded vessel by railway over a tolerably level country, I see no reason to prevent rails being laid and a cradle constructed to run upon it that will carry a loaded ship at a moderate speed through the country without risk of injury. The cradle will require to be arranged so that the bottom of the ship shall receive continuous support over as much of its surface as possible, and it should be practicable to do this so that any straining caused by this railway transport will not exceed that met with by ships under the other conditions of their employment."

There are also strong favorable opinions to be found on this side of the water, from men of acknowledged scientific and practical ability and experience. The late Edward Hartt, United States Naval Constructor, states :

"With a substantial road-bed for your railway, on the easy grades across Tehuantepec, which, I understand, do not exceed one or two feet in the hundred, there can be no mechanical difficulty in the way of transporting loaded ships by railroad with entire safety to the vessel, whether they be built of wood or iron. The ship railway plan possesses the advantage of more rapid transit for the vessels, and its capacity could easily be increased to meet the future wants of commerce."

Mr. H. L. Fernald, Naval Constructor, U. S. N., states :

"Having carefully examined the plans and papers pertaining to your proposed ship railway across the Isthmus of Tehuantepec, I do not hesitate to say that in my judgment there will be no difficulty

whatever in transporting, in the manner you propose, any properly built vessel with absolute safety."

Gen. Q. A. Gillmore, U. S. Army, states :

"In my judgment the construction of a ship railway across the Mexican Isthmus, in general accordance with your plan, is not only feasible as an engineering problem, but the successful maintenance and operation of such a road is entirely practicable as a business enterprise."

Col. Henry Flad, C. E., well known from his connection with the construction of the St. Louis bridge and other important works, states :

"First. That the first cost of the construction of a ship railroad will not be one-fourth of that of a ship canal.

"Second. That a ship railroad can be constructed in probably one-third of the time required to construct a canal.

"Third. That ships can be transported on such a railroad with absolute safety, and with the same dispatch as through a canal.

"Fourth. That the cost of maintenance will be less for a railroad than for the canal. * * *

"Fifth. That the ship railroad will, therefore, offer a safer and better investment for capital."

Commodore R. W. Shufeldt, U. S. N., states :

"I forward to you with great pleasure, an extract of a letter from Commodore Farquhar, commanding United States ship 'Quinnebaug,' at present at Alexandria, Egypt.

* * * * * * *

"'I am of the opinion that Tehuantepec possesses the best route for transit. I do not see why a railroad capable of carrying a ship could not be built, and why the long slopes of our route should not be best.

"'The fact of a harbor twenty-five miles long, on the Atlantic side, is of the utmost importance, more so than the one on the Pacific shore, because that is almost always a weather shore in that latitude.'

"I send you the extract as a disinterested opinion of an accomplished naval officer, not only as to the advantages of the route of Tehuantepec, but as to the practicability of a ship railway across the Isthmus."

Gen. G. T. Beauregard states :

"I feel no hesitancy in saying, that I see no difficulty in constructing a railway strong enough to carry out the object referred to. It is only a question of the strength of the cradle to hold the ship, and the division of weight on a sufficient number of rails and wheels, which can certainly be accomplished by any engineer of ability and

ingenuity. As to the danger a loaded ship would incur in being transported on a smooth and well-built railway, it is all imaginary."

H. D. Whitcomb, C. E., formerly member of the commission which decided in favor of the jetties at the mouth of the Mississippi river, and an engineer of recognized ability, states :

"Why should not your ship railway be practicable ? Ships have been hauled on marine railways for I know not how many years, and the hauling of larger ships a longer distance is only a development or expansion of this practice, as the steel roadway worked by locomotives is the development of the tramway, or the old incline worked by stationary power. The idea is worthy of the age, and to make it a success you have simply to improve and expand the details of the old marine railway and make it more perfect."

Very decided and favorable opinions have also been given in writing by Gen. Wm. Sooy Smith, C. E., Col. C. Shaler Smith, C. E., B. M. Harrod, C. E. and Prof. E. A. Fuertes of Cornell University, who under Com. Shufeldt made the survey of the Tehuantepec Isthmus for a canal. Many other experts of acknowledged ability have given their approval of the ship railway method and their belief in its entire practicability. We wish to add to the above the following letters recently received, one from Capt. A. K. Miller, agent of the Inman Steamship Company, at New Orleans, and well known in that section of the country as a practical expert, and one also from Mr. Epes Sargent, which speaks for itself.

"A. K. Miller & Co., Ship and Steamship Agents,
"37 Carondelet Street, New Orleans, June 18, 1885.

"E. L. Corthell, Esq., 34 Nassau Street, New York.

"Dear Sir :—I am in receipt of your esteemed letter of the 15th inst., and am much pleased to note you are quite well, and trust your enterprise will meet that support which it so justly deserves.

"In this connection, permit me to make some observations regarding your railway project for the transportation of ships across the Isthmus.

"As a practical seaman and commander of ships for many years, during which time I have had the occasion to raise and repair large ships in different styles of docks, marine railways, etc., I had formed, or rather had come to the conclusion that to raise a loaded ship in the manner proposed by Capt. Eads, and to transport her as suggested, would subject the ship to such strain that it would be simply impracticable, and could not succeed.

"While your ship railway model was on exhibition at this city, I visited it on several occasions, and after a thorough examination of the manner of raising, application of rams and distribution of

lifting power, I have but one opinion regarding the question—which is, that ships of the largest class, loaded with full cargoes can be safely lifted, and transported in the manner proposed without subjecting them to any more strain than they would undergo during a sea passage, and in fact much less fatigue than they would encounter during gales of wind such as ships are at times subjected to in all oceans of the world. I trust you will be enabled to push your work to a speedy and successful issue. Your ship railway would largely develop trade in this quarter of the globe, and would also increase shipments and traffic from the Pacific coast.

"Very truly yours, A. K. MILLER."

"Washington, June 25, 1885.

"E. L. Corthell, Esq.,

"Dear Sir:—Your letter of the 15th inst. came duly to hand. Sickness and excess of business must be my excuse for delay in answering.

"In reply to your questions, I would state that I was Manager and Superintendent of the Marine Railway at Nassau, N. P., Bahamas, for ten years, and during that time—as near as I can remember—I hauled out and repaired between 800 and 900 vessels, about one-third of which were steamers, and perhaps one-fifth of them loaded.

"As we charged so much per ton for cargo on board, as far as practicable the vessels were discharged before being taken out.

"My experience was that it was easier and safer to take out a loaded vessel than one in ballast. The railway was about 800 feet long, and similar in all respects to your model, the principle being the same. There was not one dollar's damage done to any vessel in hauling out while I had charge of the railway.

"This, I believe, answers all your questions.

"Yours respectfully, EPES SARGENT,

"338 Penna. Avenue."

The whole subject was very thoroughly canvassed by the Senate Committee of the United States Congress, and they summed up the evidence as follows:—

"The testimony upon the subject is so overwhelming and conclusive in its character that the Committee has no hesitation in reporting that the construction of a ship railway and its successful operation are entirely practicable."

It should be stated that other ship railways have been projected; one, as early as 1872 by Messrs. Brunlees and Webb, civil engineers, of Great Britain, to be built across British Honduras, on the American Isthmus, the plans for which were quite well perfected. Mr. John Fowler projected a ship railway to be built in Egypt as an

alternative plan to the Suez Canal, and also one for transferring vessels at the Third Cataract of the Nile. Mr. H. G. C. Ketchum, Mem. Inst. C. E., Great Britain, has not only projected a ship railway across the Isthmus of Chignecto, between Nova Scotia and New Brunswick, but has obtained from the Dominion government a concession by which that government guarantees one hundred and fifty thousand dollars net revenue per annum, which is about four per cent. on the estimated cost of the railway.

It remains now to show very briefly the great advantage of the ship railway over any other known method of Isthmian transit. The essential principles involved with many corroborating facts in proof, have been stated recently by us in a paper read before the American Society of Civil Engineers, at its annual convention, in June of this year, on the subject of "Canals and Railroads, Ship Canals and Ship Railways." We invite your attention to this paper for more detailed information.

About two thousand miles of canals in the United States, nearly one-half of all that have been built, have been abandoned. These abandoned canals cost originally nearly fifty million dollars. This fact alone proves that the ordinary canal cannot compete with an ordinary railway. The cause of their failure to perform, at this day, what is required of a means of transportation it is not difficult to find.

The movement of a boat in the restricted channel of a barge or ship canal is entirely different from its movement in the unrestricted water-way of the ocean. Assuming that the economical speed of a canal boat is two miles per hour, which is about correct, a speed of six miles per hour would require twenty-seven times as much expenditure of power ; that is, experiment and actual practice in many carefully noted instances show that the power required to move the boat in a canal increases as the *cubes of the velocities.* To those who desire to examine this matter further, there will be found all through the proceedings of the Institution of Civil Engineers of Great Britain, and in the reports on Canals and Railways before the British Parliament, abundant statements and illustrations, given by some of the best practical and acknowledged experts of the world, confirming our assertions. Such men as Prof. Barlow, Robert Stephenson, Mr. Bidder. Sir Robert Rawlinson, Sir John Hawkshaw, and Sir John Rennie, may be quoted as authority for the statement that canals cannot compete with railways. In an experiment made by Sir John Rennie, on the Grand Junction Canal, it was found that with a light boat of only nine inches draught, seventy feet long and four feet wide only, the power required in-

creased twenty-four fold in increasing the speed from two and a half to twelve miles an hour.

The boat or steamer in its passage through the water in a restricted channel, creates a hill up which it is constantly climbing ; the more rapid the speed the steeper the hill. Thus the boat is absolutely compelled to move at a very slow speed ; in fact it would be impossible to attain in a canal its normal ocean speed ; *the power required would be infinite.*

The history of transportation in England, since the advent of railroads—that, too, in a country specially adapted to canal transportation—shows how utterly useless it is for canals to try to compete with railroads.

Mr. James Allport, General Manager Midland Railway, stated before a Canal Committee of Parliament, in 1883, that, even in the coal business, canals could not compete with railways.

"In 30 years the railway-borne coal into London has increased from 377,000 tons in 1852 to 6,546,000 tons in 1882." The canal-borne coal in the same year was only 7,964 tons ; the canals reached some of the best coal districts of England, and were not under the control of railroads.

"I am quite sure of this, and I say it after upwards of 40 years' experience as a railway manager, that the canals cannot compete with the railways, whatever they do."

In his annual address, as President, to the Institution of Civil Engineers of Great Britain, in 1846, Sir John Rennie, speaking of the attempts to obtain speed on the canals without largely increasing the power, said : "All this, however, came too late, for although it would have been readily acknowledged at an earlier period, and might, perhaps, for a while have retarded the railway system, yet when once the latter was established its superiority became manifest and its progress became irresistible. Taken simply at the velocity of two and a half miles per hour, the resistance, or friction, offered to the tractive power by a given load is in favor of the canal, but as this resistance increases with velocity at a far greater ratio on the canal than on the railway, the advantage with the increased velocity becomes decidedly in favor of the railway."

Since 1846, railway engineers and managers have learned to build and operate with greater economy. Greater concentrated power has been applied to the locomotive, larger cars have come into use, steel rails have lessened the friction of rails and wheels, more suitable and improved running gear have reduced the axle

friction, and great improvements in the locomotive have still more lessened the friction of power. What was considered a locomotive giant hauling on a level a few five-ton "goods wagons" in 1846, would be a baby compared with the new "Decapod" of the Baldwin Locomotive Works already spoken of. The principal dimensions of this monster locomotive are as follows: Boiler, 64in. in diameter; cylinders, 22x26in.; total heating surface, 1942 sq. ft.; weight of the locomotive and tender in working order, 102 net tons. The capacity of this powerful engine is 3600 gross tons on a level.

The cost of hauling freight has been so much reduced by the numberless improvements on the railroads that 6-10 of a mill per ton per mile has been found to cover the cost of fuel, stores, train hands and repairs to locomotives. The load capacity of cars has increased from about 20,000 pounds in 1876 to 60,000 pounds in 1885. The weight of the cars, however, has increased less than 2000 pounds. In these two facts will be found the most important reasons for the reduction in the cost, of late years, of hauling freight on railways. It also goes to show what can be accomplished if this tendency is carried out to its legitimate extent. We believe the time will come, and that, too, at no distant day, when, instead of the comparatively small box, moving on two rails, in which freight is now carried, there will be hauled on the railways the immense cargo box, covering four or six rails, with a capacity of *three million* pounds, and when that day arrives freight will be hauled for *two-tenths* of a mill per ton per mile, and will not cost over *one* mill for the entire cost of operation, maintenance and general expenses. There has also been a great reduction in the cost of repairs to locomotives. On the Pennsylvania Railroad the cost has been reduced between 1865 and 1881 from $16.48 to $6.02 per one hundred miles run. The mileage of locomotives has increased from 19,240 in 1870 to 27,644 in 1881, and the average ton mileage of the locomotive has increased from 2,100,000 to 5,000,000. The three main trunk lines into New York City from the West moved, in 1883, 46,177,223 tons of freight, *increasing* the amount over four-fold since 1868; but the New York State canals in the same period *decreased* in the volume of freight from 6,442,225 tons to 5,664,056 tons. The *least expensive* method of towing on the canal is *more expensive* than the hauling on the best railways. The *running* expense on the Erie Canal at an average speed of 2.1 miles per hour, is *1 mill* per ton per mile on freight hauled by steam canal boat with consort, the least expensive method of any by canal. Including all expenses, except terminal cost and mainte-

nance of canal, the expense is 3.15 mills per ton. Even this cost is based on full loads both ways, for the boats cannot be run except at a loss, if they are sent even one way partially loaded. On Belgian Canals the cost of towing alone is nearly 5 mills per ton per mile, and on the Willebroeck Canal in England, with six to seven boats in a tow, steam towing costs 2 mills per ton running cost. These and many similar facts are gathered from a careful study of the cost of moving freight on canals and railways in England, France, Belgium and the United States.

In a letter dated August 3, 1885, from a prominent railway manager, is the following sentence: "If the tonnage which passes through this canal (Erie) was delivered for transportation to the West Shore Railway, it could be hauled and delivered more cheaply than by the water route, and in less than one-quarter of the time."

Grain is now being hauled from Chicago to Atlantic ports by the all rail route for *two mills* per ton mile.

These comparative facts and opinions are given to show the vast superiority of the ordinary railroad over the ordinary barge canal in dispatch, economy and adaptability to the wants of transportation.

If we extend the comparison and examine the relative merits of ship canals and ship railways, we will find a still greater difference in favor of the latter. The resistance to the movement of the vessel still exists, but in a greater degree; a larger mass moves through a comparatively more restricted channel. The following from London *Engineering*, February 1, 1884, discussing the effects of navigation in a contracted water-way, will give scientific confirmation of our statement:

"It is a universally recognized fact that vessels steer better, are more easily propelled and are altogether more manageable when moving through a capacious water-way.

"The vessel in motion has to be forced through the water, and the particles are thus pressed one against the other and, in confined spaces, against the bottom and sides. Thus a greater friction is kept up, which reacts upon the hull, deadens her speed and at the same time prevents an equable flow of water to her rudder, and in the case of a screw, to the propeller also; as a consequence the vessel becomes unmanageable.

"When a craft going even at moderate speed 'smells the bottom,' as the term is, she probably ends in running ashore athwart the navigation."

Mr. Scott Russell, in his "Marine Architecture," page 237, speaking

of the resistance to a vessel in passing through the restricted channel of a canal, says, "The consequences of this rapid increase of head accummulation" (in front of the vessel,) "are very serious."

"First.—It throws the ship's head up out of trim. Next.—It increases the pressure of water on her bow. Third.—It makes her travel up hill. Fourth.—It produces a backward current along her sides; and these hindrances to speed accummulate rapidly, much more rapidly than as the square of the resistance," (the rule on the ocean,) "until the amount may become insuperable; that is, many times the resistance due to the law of the square of the speed."

He proves by actual experiments that the additional resistance to that in a free water-way increases between 1 mile and $7\frac{31}{32}$ miles per hour, from *4-7* of a pound, or ton, to *128*.

"It is now necessary to notice a complimentary effect to that of accummulation in advance of the vessel—it is subsidence, or water astern. It being known, that the excavated water is sent on in advance of the vessel, it becomes plain that the channel out of which this water has been taken must have its height lowered by the subsidence of the water into the vacant canal out of which the ship has been drawn."

In the Welland Ship Canal the speed is *one* mile per hour, and the same on the North Holland Ship Canal to the port of Amsterdam—(Internal Commerce U. S., 1885, p. 494.)

In the Suez Canal—the most important ship canal in the world, the time required to pass through, one hundred miles, is *fifty* hours, or at a rate of *two* miles per hour, and about fifteen miles of the distance is through open lakes. The speed by regulation is limited to five miles, but this is a dangerous one for steamers, for they are liable to run aground.

It was stated in evidence before the Canal Committee of Parliament that in 1882 the passage of ten ships through the canal would choke it. The economical speed in a restricted channel like those proposed on the American isthmus is not over two miles per hour, and the relative running cost per ton per mile in the ship canal and on the ocean is as *three* mills to *one-half* mill, (*Six* to *one.*)

In comparing the four methods—canals, railroads, ship canals and ship railways—it may be stated that from three to four mills per ton per mile will cover the *entire* cost of moving freight on a well-managed railroad in this country, at the present time. This cost includes the numerous and expensive handlings of the goods, and the local as well as through freights. The cost of *handling* goods is

approximately the same as the cost of *hauling* for distances up to one hundred miles ; hence the immense advantage of the ship railway over the ordinary railway is seen at once in this particular. The method we have described to you, involves *no* handling ; the hatchways are not even opened. Another great advantage over ordinary railways, is, that more goods are carried at one time, thus economizing power and labor ; instead of a car moving *15* tons, as ordinarily on railroads, we have one car carrying, say *1800* tons. All the expenses per ton will consequently be largely reduced. Another fact works to the advantage of the ship railway, viz.: friction on journals increases but little with the additional weight imposed upon them. The ordinary railway places about three tons on a wheel, but the ship railway six to nine tons. The detailed estimate of the cost of hauling freight on the ship railway shows that it can be hauled from ocean to ocean for less than 30 cents per ton, allowing for maintenance, renewals, terminal expenses, turn-tables, locomotives, telegraph and incidental and general expenses, in fact all expenses, except interest on capital.

In reference to the comparative cost of construction of the ship railway and the projected canals on the Isthmus, it is difficult to give any precise facts, on account of the great discrepancy that exists between the canal estimates. The cost of the Nicaragua Canal by various estimates lies somewhere between ninety-five million and two hundred million dollars ; the Panama Canal was to have been constructed for one hundred and twenty-five million dollars, but as one hundred million and more has been expended, and not ten per cent. of the excavation has been made it is evident that the final cost will largely exceed the original estimates. It is not our purpose to draw detailed comparisons between these three methods proposed, but simply to show what can be done by the ship railway method, and the great superiority of the route over any other possible one. The objections to the two routes and methods above mentioned are briefly, as follows :

First.—The Panama Sea Level Canal.

1. Its immense cost makes it financially impracticable. It could never command a traffic that would produce a net revenue of over *one and one-half* per cent. on the invested capital.

2. The cost of maintenance will be very great. The excessive rainfall on the clayey slopes of the enormous excavations, from one hundred to four hundred feet high, will wash into the canal prism a large amount of earth and detritus, to remove which will be exceedingly expensive.

3. The control of the torrential Chagres river will be not only very expensive but doubtful. The possible breaking away of the dams and guard banks of its new channel, which is to suspend the torrent in the air, would be simply ruinous to the canal.

4. A tide lock on the Pacific—where the range of the tides is often 24 feet—the narrow restricted channel with its steep slopes, often rough and rocky, and the sharp curves in its alignment will make the passage slow, difficult and dangerous.

5. The long détour for ships, made necessary by its unfortunate location at the southern extremity of the Isthmus, will be very inconvenient and expensive to commerce.

6. Located in a region always avoided by navigators, on account of its prevailing calms, sailing commerce will be prevented from using it.

7. The unstable government and the insurrectionary character of the people, through whose country it is to be built, will lead to serious complications with other governments and danger to the integrity of the passageway.

Second.—The Nicaragua Canal.

1. The most complete and careful estimate of the cost of this work, made by Maj. W. McFarland, U. S. Engineers, is $140,000,000, with labor assumed at $1.00 per day; whereas the experience at Panama shows that this should be *doubled*, increasing the cost to at least $200,000,000.

2. The cost of restoring the ruined harbor at Greytown on the Caribbean Sea, is estimated by Maj. McFarland, at $14,000,000. The maintenance of the harbor, especially its approach and entrance, will be very difficult and expensive. The harbor on the Pacific is simply an open roadstead.

3. Its great length, 186 miles; the locks—fourteen to twenty in number—required to lift the vessels over a summit of more than 100 feet, and the restricted channel through which they must steam or be towed, will prevent an average speed of *two* miles per hour for the whole distance, including even the greater speed possible in the lake at the summit level. It will therefore require about *four days* to pass through this canal—a longer time than would be occupied by a steamer going 400 miles further south and passing through the Panama canal; the expense, also, would be greater. The *running* expense per ton to the steamer would be at least *60 cents*, while the *docking* and *hauling* over the Tehuantepec Ship Railway will be only *12 cents*. If the cost to sailing vessels is compared, the difference in favor of the Ship Railway will be still greater.

4. The location of this canal is 800 miles south of Tehuantepec a route about 1500 miles longer than that by the Ship Railway for all commerce between our Gulf and Pacific ports.

5. Its location in a feeble Central American State; the dispute between Nicaragua and Costa Rica, as to the right to the territory to be traversed by the canal; the complications existing between England and the United States through the Clayton-Bulwer treaty and the indefensibility of the approaches, make it most unwise for this country to undertake the work, or become in any way complicated with it.

The ship railway is above the floods and built upon the surface of the ground, and is therefore not subject to those conditions that often render the maintenance of works expensive and sometimes impracticable; it is capable of indefinite enlargement; the cost of moving vessels is less than the cost of steaming or towing through either of the canals.

A very liberal concession was granted for the ship railway by the Mexican Government, May 28, 1881.

It provides for the construction and operation for ninety-nine years of a ship railway with its corresponding lines of telegraph across the Isthmus of Tehuantepec. The right of way is granted eight hundred metres wide, reduced in town lands to four hundred metres, and increased where stations are necessary to sixteen hundred metres. The public lands within this belt are conceded gratis to the company. Full authority is given for the prompt condemnation of all private lands needed. Four thousand two hundred square kilometres of public lands, equal to a million acres, are granted in aid of the enterprise. The right is given to import free of duty all kinds of machinery, instruments, coal and materials necessary for the construction, operation and maintenance of the works during ninety-nine years.

Vessels, passengers and merchandise in transit, will be free of all kinds of duties, general as well as local, during the time of the concession.

The property and capital invested in the enterprise, its bonds and shares of stock are exempted from all taxation or contribution of any kind, except that of revenue stamps, the Constitution of Mexico prohibiting the release of the latter tax by Congress.

Authority is given to collect a maximum toll on each vessel not exceeding five dollars per cubic metre, for each metre contained in a parallelopipedon, of which the dimensions shall be the greatest

length and the greatest breadth of the vessel measured at the surface of the water, and her greatest immersed depth. This would be about $8.00 per ton on the cargo carried. For each passenger carried across, a sum of not exceeding $15.00 may be charged.

Gold and silver and precious stones may be charged a maximum rate not greater than one per cent. of their value.

The right is granted to collect wharfage dues and tonnage dues not exceeding $1.00 per registered ton.

Passage over the railway shall be open for all the vessels of all the nations not at war with Mexico, and the Republic binds itself not to close to ocean commerce during the term of the concession either of the two terminal ports of the ship railway, one in the Gulf, the other in the Pacific, except in case of war.

In consideration of the magnitude of the work, the company may obtain aid from any foreign government either in money or in guarantees, and hypothecate the net revenues to it, and may transport its mails, ships, property, and appurtenances free of charges, and may reduce the tariffs on its commerce, and the prices of passage.

In the event of failure on the part of the company to comply with any such stipulations made with a foreign government, such foreign government shall have the right to enforce its claims before the courts of Mexico, in accordance with the laws of Mexico, but in no case can such foreign government acquire the ownership of the works, or the rights emanating therefrom.

The commercial advantage of the Tehuantepec Ship Railway may be seen from the present expense of shipping goods by the various routes. The cost of freight from San Francisco to New York, by the Cape Horn route, is $10.00 to $15.00 per ton ; on grain to Liverpool an average of $16.00 ; over the Panama railroad $20.00 to $25.00 ; over the trans-continental railroads, $25.00 to $30.00. The Tehuantepec route will save one-half the distance over the Cape Horn route, and will practically reduce the cost one-half. The saving in distance on the main routes of commerce by the Tehuantepec route may be seen by the following table of comparative distances, compiled by the United States Coast Survey :

TABLE OF COMPARATIVE DISTANCES IN STATUTE MILES.

	Total Distance.	Excess over Tehuantepec Route.
FROM NEW YORK TO HONG KONG.		
Via Cape Horn	20,379 miles.	8,777 miles.
Cape of Good Hope	16,945 "	5,343 "
Suez Canal	13,596 "	1,994 "
Panama R. R.	12,953 "	1,351 "
Isthmus of Tehuantepec	11,602 "	.... "
NEW YORK TO YOKOHAMA.		
Via Cape Horn	19,802 "	9,796 "
Cape of Good Hope	18,085 "	8,079 "
Suez Canal	15,527 "	5,521 "
Panama R. R.	11,256 "	1,250 "
Isthmus of Tehuantepec	10,006 "	.... "
NEW YORK TO AUCKLAND, N. Z.		
Via Suez Canal	16,871 "	7,447 "
Cape of Good Hope	16,719 "	7,295 "
Cape Horn	13,890 "	4,466 "
Panama R. R	10,305 "	881 "
Isthmus of Tehuantepec	9,424 "	.... "
NEW YORK TO MELBOURNE.		
Via Cape Horn	15,215 "	4,150 "
Suez Canal	15,171 "	4,106 "
Cape of Good Hope	15,019 "	3,954 "
Panama R. R.	11,826 "	761 "
Isthmus of Tehuantepec	11,065 "	.... "
NEW YORK TO HONOLULU.		
Via Cape Horn	15,826 "	9,163 "
Panama R. R.	7,939 "	1,276 "
Isthmus of Tehuantepec	6,663 "	.... "
NEW YORK TO SAN FRANCISCO.		
Via Cape Horn	15,687 "	10,797 "
Panama R. R.	6,063 "	1,173 "
Isthmus of Tehuantepec	4,890 "	.... '
LIVERPOOL TO HONG KONG.		
Via Cape Horn	20,606 "	5,353 "
Panama R. R.	16,471 "	1,218 "
Cape of Good Hope	15,722 "	469 "
Isthmus of Tehuantepec	15,253 "	.... "
LIVERPOOL TO YOKOHAMA.		
Via Cape Horn	19,400 "	5,945 "
Cape of Good Hope	17,653 "	4,198 "
Panama R. R	14,540 "	1,085 "
Isthmus of Tehuantepec	13,455 "	.... "
LIVERPOOL TO AUCKLAND, N. Z.		
Via Cape of Good Hope	16,221 "	3,412 "
Suez Canal	14,645 "	1,836 "
Cape Horn	13,897 "	1,088 "
Panama R. R.	13,312 "	503 "
Isthmus of Tehuantepec	12,809 "	.... "

TABLE OF COMPARATIVE DISTANCES IN STATUTE MILES.

	Total Distance.		Excess over Tehuantepec Route.	
LIVERPOOL TO SAN FRANCISCO.				
Via Cape Horn	15,803	miles.	7,527	miles.
Panama R. R	8,885	"	609	"
Isthmus of Tehuantepec	8,276	"	....	"
NEW ORLEANS TO HONG KONG.				
Via Cape Horn	20,804	"	10,531	"
Cape of Good Hope	17,485	"	7,212	"
Suez Canal	15,108	"	4,835	"
Panama R. R	12,308	"	2,035	"
Isthmus of Tehuantepec	10,273	"	....	"
NEW ORLEANS TO YOKOHAMA.				
Via Cape Horn	20,227	"	11,590	"
Cape of Good Hope	18,625	"	9,988	"
Suez Canal	17,039	"	8,402	"
Panama R. R	10,611	"	1,974	"
Isthmus of Tehuantepec	8,637	"	....	"
NEW ORLEANS TO AUCKLAND, N. Z.				
Via Suez Canal	18,381	"	10,286	"
Cape of Good Hope	17,259	"	9,164	"
Cape Horn	14,314	"	6,219	"
Panama R. R	9,659	"	1,564	"
Isthmus of Tehuantepec	8,095	"	....	"
NEW ORLEANS TO MELBOURNE.				
Via Suez Canal	16,683	"	6,947	"
Cape Horn	15,640	"	5,904	"
Cape of Good Hope	15,560	"	5,824	"
Panama R. R	11,181	"	1,445	"
Isthmus of Tehuantepec	9,736	"	...	"
NEW ORLEANS TO HONOLULU.				
Via Cape Horn	16,251	"	10,917	"
Panama R. R	7,294	"	1,960	"
Isthmus of Tehuantepec	5,334	"	....	"
NEW ORLEANS TO SAN FRANCISCO.				
Via Cape Horn	16,112	"	12,551	"
Panama R. R	5,418	"	1,857	"
Isthmus of Tehuantepec	3,561	"	....	"
NEW YORK TO VALPARAISO.				
Via Cape Horn	10,051	"	3,682	"
Panama R. R	5,417	"	....	"
Isthmus of Tehuantepec	6,369	"	....	"
NEW ORLEANS TO VALPARAISO.				
Via Cape Horn	10,476	"	5,436	"
Panama R. R	4,772	"	....	"
Isthmus of Tehuantepec	5,040	"	....	"

The Tehuantepec Route has some special advantages:—The great increase in wheat production on the Pacific coast and the still more rapid development certain to follow the opening of the Ship Railway, give an assurance that fully one quarter of the tonnage will be wheat. On account of remaining so long in the tropics the Underwriters are not willing to insure it except in bags, which cost $2,000,000 per annum, or $1.51 per ton, or 4 cents per bushel. This expense can be saved by the Tehuantepec Route, for it is scarcely further south than the Florida straits. The average extra cost per ton by the longer distance and time required by the Panama and Nicaragua Routes, is 50 cents. This saving is made on both steamers and sailing ships. Thus we have a total advantage of $2.01 per ton, saying nothing of the excess in cost of canal over ship railway transportation.

Another important commercial advantage is seen from the following facts: First. The distance from New York to the Pacific at Tehuantepec is nearly *1000 miles shorter* than across the continent. Second. *Seventy* per cent. of the far Pacific trade is from countries lying *south of Tehuantepec.* Third. The distance from Liverpool to many Pacific ports is shorter by Tehuantepec than by Suez. The present through business by the trans-continental railroads, from countries west of San Francisco, is comparatively unimportant, and it is so, and must remain so, from the fact that the Suez and Cape Horn routes have the advantage by not requiring trans-shipment. These latter and the Panama Railroad are the routes that the Ship Railway will compete with successfully, and from which it will draw an immense business. By the time the ship railway is opened the trans-continental railroads will have found, in the vast and rapidly developed country which they traverse, all the business they can handle—business that has its source in the country lying between the Atlantic and Pacific, and which the ship railway can never reach. There is, therefore, no rivalry between the two. The real rivalry will be with routes with which the railroads cannot possibly compete.

The *strategic* advantage cannot be over-estimated. If Mexico and the United States should guarantee the protection of the Railway it will not be possible for all the world to interfere with it. There are five lines of railways building from the United States into Mexico, by which an army of 100,000 men could be concentrated at the Isthmus in a few days, and our navy could easily defend the approaches, especially on the Gulf. The capacious and naturally protected

harbors, one in the Coatzacoalcos 25 miles in length, and the other in Lake Superior on the Pacific, furnish excellent harbors of refuge for commerce.

This route is essentially *American*, benefiting as it does, more than any other, the commerce of this country.

The tonnage that may be expected on completing the Ship Railway has been ascertained in detail from reliable sources. It is given in following table :

DETAILED STATEMENT OF TONNAGE EXPECTED OVER THE SHIP RAILWAY

In 1889.

Routes by which Commerce Moves.	**Tons 1883.** Actual Tonnage carried by steam and sail on routes longer than via Tehuantepec.	**Tons 1889.** Estimated from ratio of increase of commerce on the routes from 1879 to 1883, and from new business to be developed.
1. Panama Railroad	77,958	60,000
2. U. S. Pacific Coast with Atlantic via Cape Horn	237,341	359,081
3. Atlantic Ports with Countries west of Cape Horn	349,454	489,135
4. U. S. Pacific Coast with foreign Countries east of Cape Horn	1,423,737	2,135,605
5. European Countries with Countries west of Cape Horn, other than U. S.	1,828,621	2,285,776
6. British Columbia (Pacific Coast) with Europe	125,000	235,000
7. Slow bulky freights now going over Transcontinental lines	400,000	600,000
8. Fifty per cent. of tonnage now going from Asiatic Countries to Europe via Cape of Good Hope	400,000	400,000
9. New trade to be developed by Ship Railway between Gulf Ports of U. S. and Mexico and Pacific Ocean	....	1,000,000
Total,	4,842,111	7,564,597

The total of 7,564,597 tons very closely agrees with the estimate of the Panama Canal Congress, held in 1879, made on an entirely different basis, and estimated for a less advantageous route.

The net income that can reasonably be anticipated on even four million tons is $10,800,000, or 14½ per cent. on $75,000,000 capital, in stock and bonds. With the rapid and steady development

of commerce, and with the immense advantage of this route and method, we may assuredly expect a rapid increase in the tonnage transported; therefore, not only commerce but capital will find it profitable to encourage and assist this great enterprise.

The important results that will certainly follow the construction of this great work can hardly be conceived of; beneficial to commerce, and through it to the world's varied and growing industries.

When the Ship Railway is completed and ships pass from ocean to ocean, the last barrier to commerce will have been removed. The world then will be literally *circumnavigable*. The race will then possess those commercial, industrial, political, social and religious advantages that have become more and more imperative as civilization and religion have sought out the nations and exerted upon them their benign influences.

It has been well said: "The chief element in the prosperity of every State and Nation is the economy of transportation of persons and property. It is the most marked fact in the difference between civilization and barbarism." In assisting such an enterprise as the Tehuantepec Ship Railway, we are working in the true line of progress and for the advancement of the race in all its highest possibilities and its loftiest purposes.

This project we have discussed is the conception and the work of no impractical enthusiast and visionary. The important victories gained on the Mississippi River, in the civil war, by the formidable iron clad fleet built at St. Louis; the massive piers founded, for all time to come, on the bed rock of the mighty river, one hundred feet down through the shifting quicksands; the graceful arches that span the turbid flood; the deep and commodious channel for commerce at the mouth of the Great River, carved through the obstructing sand bars—all are sureties that the projector and promoter of this grander plan, has himself solved the problems, met the difficulties, appreciated and overcome the obstacles, and that he will, with the aid of Science and the broad-minded statesmen of these two sister republics, and the enlightened capital of the world, complete the work that will be left as a grand heritage to posterity and an enduring monument to the constructive genius of James B. Eads. His high purpose and firm resolve can best be told in his own words spoken, not long since before a Boston audience:

"We propose to bring the Golden Gate eleven thousand miles nearer by sea to Plymouth Rock than it is to-day. We propose to open a

direct line from the Atlantic Seaboard to six hundred millions of people on the islands and shores of the Pacific who need, not only the products of Boston, her mills, her factories and her workshops, but also the elevating and Christianizing influences which will flow from a more intimate intercourse with her men and women, and a more extensive knowledge of the institutions of art, science, literature and benevolence, which illuminate and adorn the nations of the Atlantic. This is our task.

"When this work is completed, as I am sure it will be, and that long before a canal is cut across the American Isthmus, its benefits will be felt by our fellow men all over the world; not only in lessening the cost of transportation on the necessaries and luxuries of life, and in shortening the long weary, trackless distances which now separate nations from each other, and by opening new markets for the multitude of commodities which are interchanged by the various peoples of the earth, but also by bringing distant communities into more intimate social and commercial relations with each other, whereby the better sympathies and sentiments of each will be promoted, their prejudices removed, the amenities of life increased, and the benefits of civilization, science and religion more surely tend to the increase of 'peace on earth, good will to men.'

"This work, when finished, will be the realization of the ardent wish of statesmen and philanthropists everywhere; the dream of kings and conquerors during the last three hundred and fifty years, and a fitting supplement to the grand achievements which have marked the progress of the nineteenth century."

DESCRIPTION OF PLATES.

Referring to Plate I, of detailed illustrations.

Fig. 1 shows the process of running down the adjusting nut of the supports to a bearing on the plates of the cross girders. The details of the support are shown in Fig. 4, with the hydraulic ram forcing it up to its position under the vessel. *A*, is the rod with the thread cut in it; *B*, the adjusting nut; *C*, the girder; *D*, the ram.

Fig. 2, Cross-section of the pontoon, towers and carriage. *A*, is a side support; *E*, *G*, *F*, the adjustable hinged girth; *D*, the ram; *LL*, the towers for the pressure pumps which are on the top of the towers; *I*, is the pipe through which the water is withdrawn from the pontoon by the centrifugal pump; *J*, is the reservoir from which the water is taken to force a pressure through the pipes to the rams; *K*, is one of the cylinders for the hydraulic governors.

Fig. 3, shows a part of the deck of the pontoon with the rails and the lines of rams projecting above the deck.

Plate II, shows plan and detail of railway carriage.

Plate III, is a perspective view of the pontoon and railway cradle.

Plate IV, exhibits perspective view, plan and sectional elevation of the floating turn-table.

Plate V, is a view of a steamer in transit.

Plate VI, map of Isthmus of Tehuantepec and location of Ship Railway.

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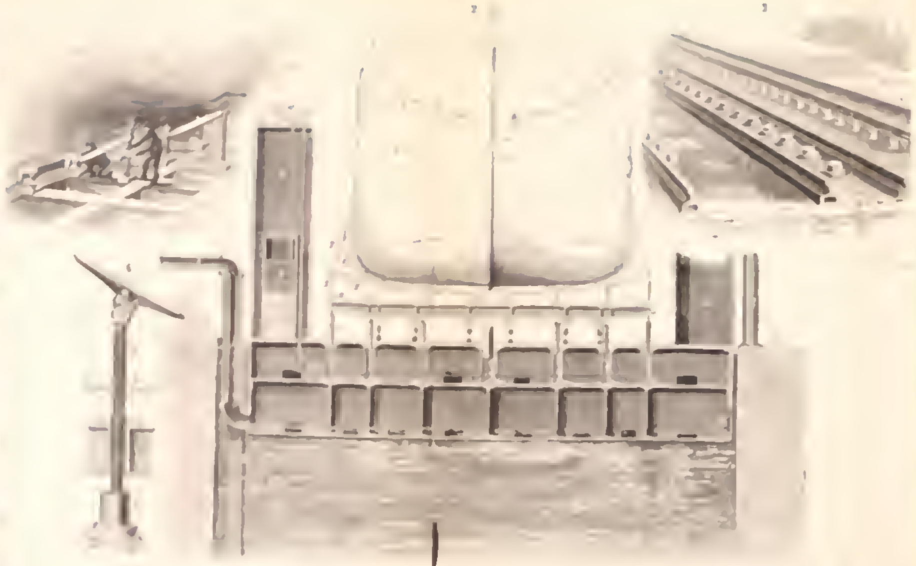
Plate I



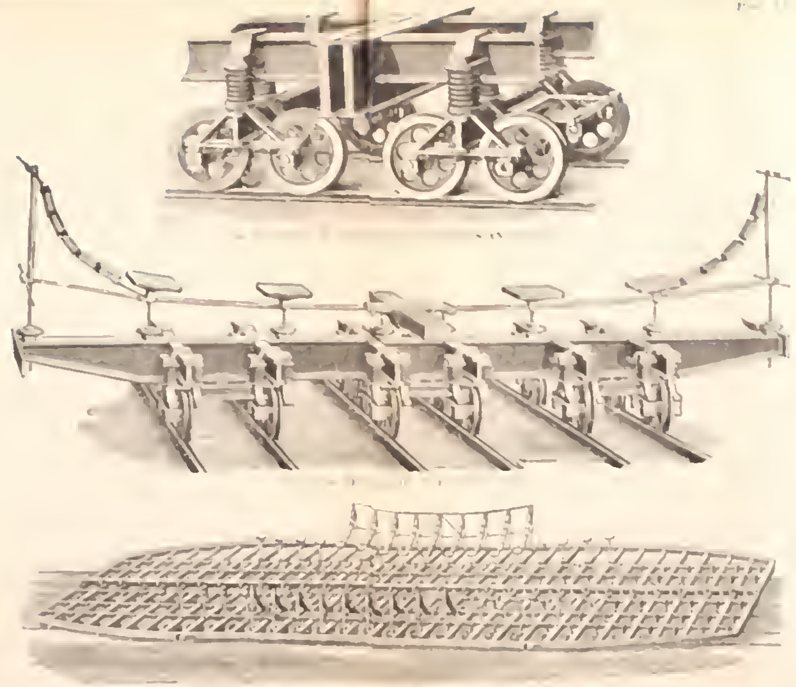


Plate III

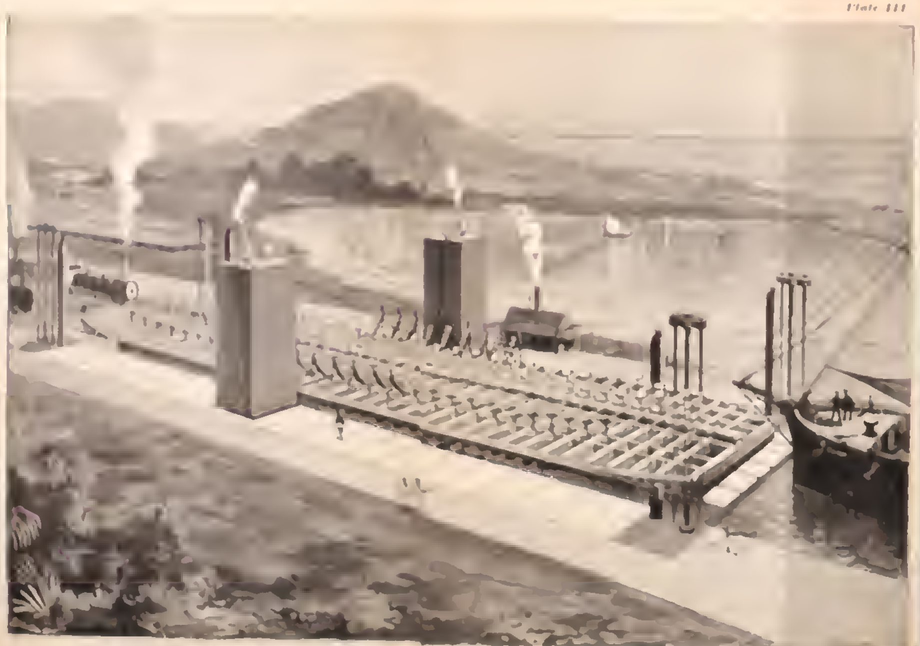
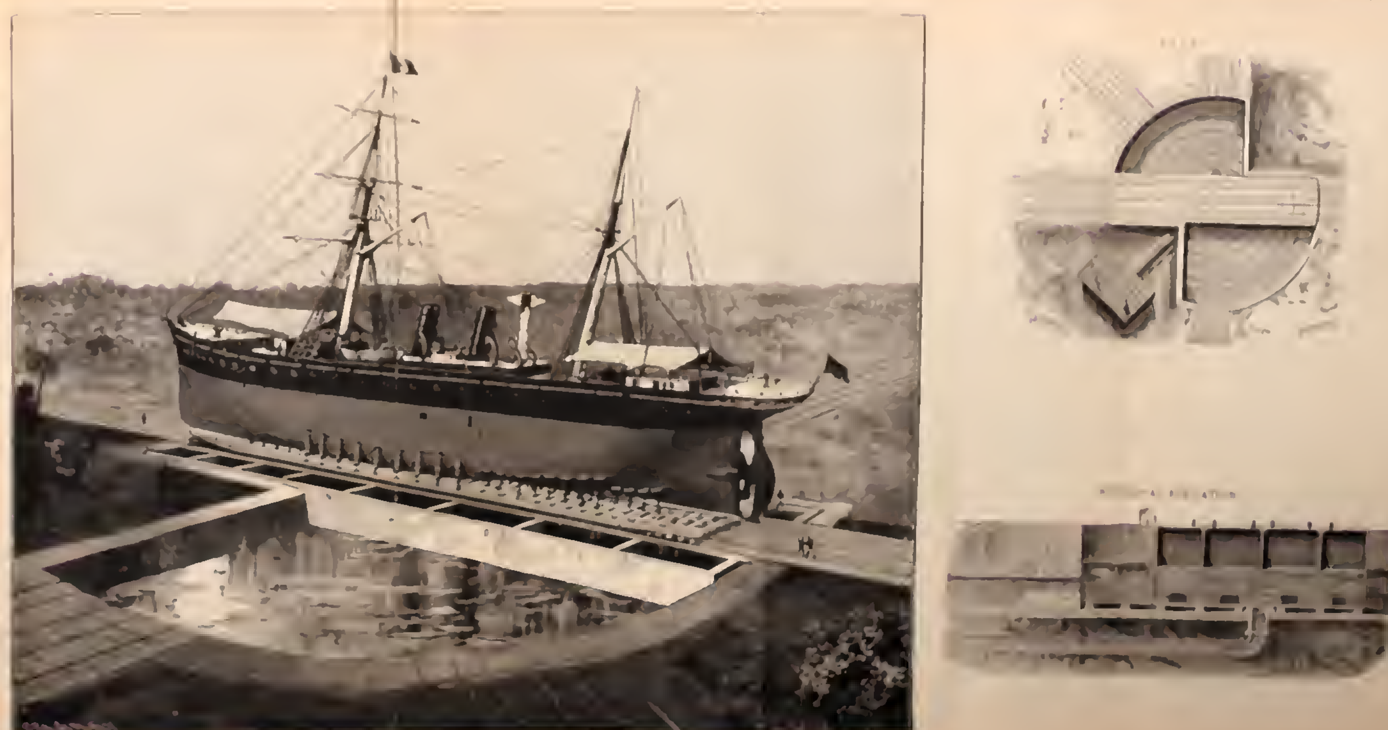


Plate II



Map of the
TEHUANTEPEC SHIP RAILWAY
UNITED STATES OF MEXICO.
GULF OF MEXICO